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# EFFECT OF DREDGED BOTTOM SEDIMENT ADDITION TO THE SUBSTRATUM ON THE FODDER VALUE OF PLANT MATERIAL Part 2. QUANTITATIVE RATIOS BETWEEN MACROELEMENTS

## WPŁYW DODATKU BAGROWANEGO OSADU DENNEGO DO PODŁOŻA NA WARTOŚĆ PASZOWĄ MATERIAŁU ROŚLINNEGO Cz. 2. STOSUNKI ILOŚCIOWE MIĘDZY MAKROELEMENTAMI

**Abstract:** Pot experiments were conducted in 2004 and 2005 on substrata prepared from soil and quartz sand together with bottom sediment dredged from the Roznow Reservoir. The investigations aimed at an assessment of increasing supplements of the bottom sediment to the substratum on the quality of cultivated plant biomass. The assessment criteria were values of quantitative ratios between macroelements in the biomass. Assessed were weight Ca:Mg and Ca:P ratios and K:Na and K:(Ca+Mg) ionic ratios.

Values of Ca:P ratio in the unicotyledonous plants from the control objects were too low, whereas in the dicotyledonous too high. The sediment supplement considerably widened this ratio but generally worsened the quality of obtained biomass. With growing proportion of the sediment in the substratum a widening of Ca:Mg weight ratio was observed and narrowing of K:(Ca+Mg) ionic ratio, which worsened the biomass quality. Only in case of barley cultivated in the second year of the experiment a positive effect of the sediment on the analyzed indices of fodder quality was observed. K:Na ratio in biomass of all plants was too wide and the sediment added to the substratum improved this parameter value. Greater changes of the analyzed ratios value were registered in the plants growing on substrata with sand as compared with the substrata based on light soil. A stronger influence of the bottom sediment on shaping quantitative interrelations between the analyzed macroelements was found in the dicotyledonous than in the unicotyledonous.

Bottom sediment affects shaping quantitative ratios between elements in plant biomass in a similar way as liming, therefore agricultural application of dredged sediment as a deacidifying material is possible, however worsening of some indices of plant fodder value should be taken into consideration.

**Keywords:** bottom sediment, relationships between macroelements, fodder value

Technical degradation of dam reservoirs has been currently the most important problem in their operation. Their silting results in limited possibilities of a hydroelectric

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plant operation and in future may cause problems with potable water supply for many cities [1]. Dredging of dam reservoirs is the only efficient method to recover their primary functions [2]. Therefore, in future it will be necessary to remove the sediments from reservoir regardless of the costs of such endeavours [3]. In Poland most areas are susceptible to erosion which entails more rapid silting of dam reservoirs. The Roznow Reservoir is the fastest silting dam reservoir in Poland and after 50 years of its operation its length decreased by 40 %. Reclamation measures are crucial for prolonging operation time of this reservoir [4]. Dredging produces a great mass of sediment which should be managed. Bottom sediments are the main link in matter cycling in the water ecosystem providing a reservoir of many elements, which were periodically inactivated [5]. A partial dredging of the Roznow Reservoir started in 2003. The removed sediment was stored on the lagoons formed from a part of the reservoir bowl [6]. Such method of sediment utilization diminished the reservoir area and makes impossible its total reclamation. Bottom sediment excavated during dredging usually have alkaline reaction and large content of fraction of silt and clay, therefore they may reveal similar effect as waste rocks [7], so they may be regarded a valuable material for improving light acid soils properties.

The experiments aimed at an assessment of potential management of the dredged bottom sediment in agriculture. The assessment criterion was fodder value of plant biomass obtained on the substrata to which the sediment supplements were added. The plant material was evaluated on the basis of reciprocal quantitative relations between macroelements in the biomass.

## Material and methods

The pot experiments were conducted in 2004–2005 on the substratum composed of light soil or quartz sand, to which bottom sediment dredged from the Roznow Reservoir was added (Table 1).

Table 1

Selected properties of substrata components used in experiments

| Component | $pH_{KCl}$ | P | Mg | Ca | Na | K | P | $K_2O$ |
|---|---|---|---|---|---|---|---|---|
| | | total content [$g \cdot kg^{-1}$] | | | | | available forms [$mg \cdot kg^{-1}$] | |
| Sediment | 7.2 | 0.532 | 3.833 | 17.46 | 0.973 | 8.632 | 18.0 | 96.6 |
| Soil | 5.82 | 0.392 | 0.564 | 1.038 | 0.084 | 0.556 | 63.3 | 256 |
| Sand | 6.39 | 0.072 | 0.824 | 0.417 | 0.091 | 0.459 | 4.45 | 19.2 |

The experimental design comprised 11 combinations of substrata in three replications. The sediment share in the substratum was increasing from 10 to 100 %, regularly by 10 % on the subsequent treatments. The control objects were soil and sand without the sediment admixture. Basic fertilization of 1 g N, 0.25 g P and 1.25 g K per pot was applied for all treatments and thoroughly mixed with the substratum. Chemically pure

$NH_4NO_3$, $KH_2PO_4$ and KCl were used. The test plants were maize (*Zea mays* L.), 'Prosna' F1 c.v., and horse bean (*Vicia faba* L.), 'Nadwislański' c.v., as a consecutive plant, and oat (*Avena sativa* L.), 'Chwat' c.v., and narrowleafed lupine (*Lupinus angustifolius* L.), 'Sonet' c.v., as a consecutive plant. In the experiments continued on the same substrata in 2005 spring barley (*Hordeum vulgare* L.), 'Rambo' c.v., was cultivated as the test plant. After harvest the plant material was dried, the samples were dry mineralized and macroelements were assessed after the ash dissolving in $HNO_3$ (1:2) using ICP-AES method. On the basis of macroelement contents in the aerial plant biomass Ca:P and Ca:Mg weight ratios were computed, as well as K:Na and K:(Ca+Mg) ionic ratio.

## Results and discussion

An assessment of plant fodder value on the basis of their chemical composition does not provide full information about their ability to meet animal nutritional needs for micro- and macroelements. At plant utilization for feeds the quantitative relations between the elements are often more important criterion of their usability than the contents of individual elements in the biomass. Too high content of one element may synergistically or antagonistically affect the other components causing their limited or excessive absorption by animal organisms. The proper ratio between elements in feed affects their bioavailability and thus the healthiness and productivity of animals [8]. Wrong proportions between the nutrients may also negatively affect plant growth and development. Too high calcium content in the substratum causes reduced uptake of phosphorus, magnesium and most other microelements, which leads to so-called apparent element starvation. In order to assess fodder value of the plants obtained in the experiment the most important ionic and weight ratios were computed between the macroelements in their biomass.

Ca:P weight ratio in the obtained plants ranged from 0.93 to 22.0 (Table 2).

Lupine revealed the widest, while barley the narrowest calcium to phosphorus ratio. The lowest values of this parameter were observed in all control plants growing in the soil and sand. A 10 % admixture of the sediment to the substratum already caused several-fold widening of this ratio in plants cultivated first. In legumes biomass cultivated as consecutive plants, this parameter value widened to a lesser degree. In the second year of the experiment less than twofold widening of Ca:P weight ratio was registered in barley biomass under the influence of the smallest sediment supplement. Bigger admixtures of the sediment to the substratum did not cause any more changes of this parameter value, except for the legumes in which further widening was observed at the sediment admixture reaching up to 30 % of the substratum mass. Generally higher values of this parameter were assessed in the plants grown on substrata with sand than with soil.

The largest diversification of Ca:P ratio (RSD %) in biomass of plant grown on substrata with soil was observed for lupine and on substrata with sand for horse bean and the smallest one on both kinds of substrata was found for barley.

Table 2

Values of weight calcium : phosphorus ratio (Ca:P) in plant biomass

| Share of sediment in substratum [%] | Substratum with soil | | | | | Substratum with sand | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | maize | oat | horse bean | lupine | barley | maize | oat | horse bean | lupine | barley |
| | Ca:P | | | | | | | | | |
| 0 | 0.95 | 1.62 | 3.07 | 4.64 | 1.24 | 1.37 | 0.93 | 2.67 | 4.17 | 1.34 |
| 10 | 4.19 | 3.59 | 6.54 | 6.24 | 2.15 | 4.77 | 3.35 | 9.59 | 11.94 | 2.25 |
| 20 | 4.50 | 3.65 | 9.72 | 16.72 | 2.61 | 4.97 | 3.22 | 12.38 | 12.98 | 2.63 |
| 30 | 3.82 | 2.67 | 9.08 | 13.42 | 2.38 | 4.50 | 2.69 | 11.79 | 18.68 | 2.49 |
| 40 | 4.85 | 2.61 | 9.48 | 10.50 | 2.26 | 5.16 | 2.98 | 10.95 | 16.73 | 1.94 |
| 50 | 4.97 | 2.71 | 10.19 | 21.46 | 1.76 | 4.98 | 3.12 | 11.00 | 17.76 | 2.01 |
| 60 | 4.34 | 2.25 | 12.06 | 18.81 | 2.47 | 4.85 | 3.38 | 6.73 | 13.73 | 2.56 |
| 70 | 5.12 | 2.82 | 12.66 | 18.32 | 2.13 | 5.33 | 4.05 | 5.04 | 15.46 | 2.00 |
| 80 | 4.56 | 3.16 | 15.06 | 16.41 | 2.42 | 4.89 | 2.41 | 6.34 | 16.83 | 2.58 |
| 90 | 4.76 | 1.97 | 11.89 | 22.01 | 2.24 | 4.65 | 2.36 | 2.37 | 14.75 | 2.35 |
| 100 | 4.75 | 2.96 | 10.47 | 18.75 | 2.76 | 4.75 | 2.96 | 10.47 | 18.75 | 2.76 |
| Mean | 4.26 | 2.73 | 10.02 | 15.21 | 2.22 | 4.57 | 2.86 | 8.12 | 14.71 | 2.26 |
| SD | 1.16 | 0.62 | 3.19 | 5.85 | 0.42 | 1.08 | 0.80 | 3.65 | 4.16 | 0.41 |
| RSD | 27.19 | 22.86 | 31.86 | 38.44 | 18.89 | 23.75 | 27.88 | 44.90 | 28.30 | 18.31 |

Explanation for Tables 2–5: SD – standard deviation, RSD – relative standard deviation [%].

The optimal Ca:P ratio is 2:1 [9]. Even the smallest addition of the sediment to the substratum exceeded the recommended value for all plants, except barley cultivated in the second year of the experiments, in which it was observed that C:P ratio remained on a level approximate to optimal at each sediment supplement to the substratum. Value of Ca:P weight ratio in the analyzed plants was changing apparently under the influence of bottom sediment admixture to the substratum. In research conducted by Wyszkowski [10] mean values of this parameter in barley and oat biomass at the flowering stage were 0.89 and 0.59, respectively. These values were slightly lower than in plants on the control objects in the presented experiments. Ca:P weight ratio in horse bean leaves and straw assessed in Wyszkowska's investigations [11] reached values within the range of 10–15, whereas this ratio value in horse bean straw oscillated around 10 [12]. In the research conducted by Traba et al [13] the value of Ca:P ratio in legumes gathered from meadow sward of the San River valley and Dynowskie Highland fluctuated from 5 to 10. Kochanowska and Nowak [14] estimated that values of this ratio in meadow hay ranges from 1.3 to 2.7. Labuda et al [15] registered widening of Ca:P ratio to 2.4 in oat biomass at panicle appearance stage under the influence of liming, whereas this ratio value in the control plants in their experiment was 1.9. The values of weight ratios from the control objects obtained in the Author's own experiments were approximate to literature data, however at increased share of the sediment in the substratum their interrelations were widening, reaching considerably higher values than considered optimum for plants designed for feeds. The main factor generating changes of Ca:P weight ratios in maize and oat biomass was phosphorus content in these plants. In effect of the sediment admixture to the substratum phosphorus uptake by the plants decreased considerably, reaching much lower values than optimum in fodder plants [9]. In horse bean and lupine biomass increased calcium accumulation was observed simultaneously to decreasing phosphorus value.

Ca:Mg weight ratio in plant biomass produced on all experimental treatments ranged from 2.21 to 16.64 (Table 3).

Table 3

Values of weight calcium : magnesium ratio (Ca:Mg) in plant biomass

| Share of sediment in substratum [%] | Substratum with soil | | | | | Substratum with sand | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | maize | oat | horse bean | lupine | barley | maize | oat | horse bean | lupine | barley |
| | Ca:Mg | | | | | | | | | |
| 0 | 2.75 | 5.61 | 9.02 | 10.57 | 5.35 | 2.33 | 2.60 | 8.84 | 6.54 | 4.59 |
| 10 | 2.99 | 7.68 | 12.42 | 6.97 | 6.80 | 2.88 | 6.71 | 12.48 | 13.05 | 5.05 |
| 20 | 2.91 | 6.40 | 13.32 | 15.14 | 6.27 | 2.67 | 6.99 | 12.62 | 14.17 | 8.02 |
| 30 | 2.40 | 5.08 | 12.10 | 12.98 | 4.65 | 2.68 | 5.82 | 13.26 | 16.64 | 5.39 |
| 40 | 2.72 | 4.85 | 13.13 | 7.74 | 4.56 | 2.82 | 5.22 | 10.91 | 11.22 | 4.42 |
| 50 | 2.73 | 4.45 | 10.11 | 13.97 | 3.19 | 2.68 | 6.34 | 10.49 | 13.16 | 3.73 |
| 60 | 2.51 | 4.98 | 11.84 | 12.41 | 3.53 | 2.67 | 6.39 | 8.26 | 12.36 | 4.01 |
| 70 | 2.43 | 4.64 | 10.17 | 14.23 | 3.44 | 2.50 | 6.36 | 6.63 | 12.46 | 3.45 |
| 80 | 2.80 | 4.81 | 10.82 | 13.31 | 3.33 | 2.22 | 5.16 | 7.76 | 12.77 | 3.30 |
| 90 | 2.33 | 3.60 | 11.51 | 14.14 | 2.95 | 2.37 | 5.54 | 7.87 | 12.68 | 3.08 |
| 100 | 2.21 | 5.33 | 9.39 | 13.36 | 3.46 | 2.21 | 5.33 | 9.39 | 13.36 | 3.46 |
| Mean | 2.62 | 5.22 | 11.26 | 12.26 | 4.32 | 2.55 | 5.68 | 9.86 | 12.58 | 4.41 |
| SD | 0.25 | 1.07 | 1.46 | 2.70 | 1.32 | 0.23 | 1.20 | 2.24 | 2.42 | 1.41 |
| RSD | 9.68 | 20.58 | 13.00 | 22.01 | 30.57 | 9.22 | 21.07 | 22.71 | 19.24 | 31.98 |

Mean value of this parameter in all plant biomass was 7.08. The highest values of Ca:Mg ratio were registered in horse bean and lupine, while the lowest in maize. In the response to a 10–20 % sediment addition to the substratum a widening of Ca:Mg ratio in all plant biomass happened, except for lupine cultivated on the substrata with soil. Higher supplements of the sediment resulted in narrowing of this ratio and in plants cultivated in the sediment itself it was as a rule lower than observed in the control plants. The exception were oat and lupine on substrata prepared on the basis of sand, where a considerable widening of Ca:Mg ratio was observed under the influence of the sediment addition to the substratum.

The largest diversification of Ca:Mg ratio (RSD %) in biomass of plant grown on both kinds of substrata was observed for barley and the smallest one for maize.

Optimum Ca:Mg ratio in good quality feeds is 3:1 [16]. Bottom sediment supplement constituting 20–30 % of the substratum mass generally worsened the quality of the obtained plants assessed according to fodder usability criteria, whereas bigger supplements of the sediment improved the quantitative interrelations between calcium and magnesium. Values of Ca:Mg weight ratios were changing to a lesser degree than Ca:P ratio because of usually observed positive relationship between the contents of both elements, which was a consequence of their high concentrations in the sediment. In research conducted by Brogowski et al [18] the value of this ratio in barley biomass at shooting stage was about 2. In legumes gathered from the meadow sward in the San River valley the ratio assumed the value about 3.5 [13]. In horse bean straw the mutual ratios of these elements reached the value of 15 [12]. It might have been caused by a decrease in magnesium content in all plants, except for maize, as well as considerable increase in calcium content. Gorlach and Curylo [19] obtained similar results; the same authors observed widening of Ca:Mg ratio in maize biomass from 1.6 in the control plants to 2.44 after application of calcium in the amount equal to the value of 2 hydrolytic acidity. High values of Ca:Mg ratio were caused by a very small magnesium content in the plants from these experiments. Too high values of Ca:Mg ratio may cause hypercalcemia in animals, which is seen as a apparent starvation of other elements [16].

K:Na ionic ratio fluctuated between 4 and 192 and mean for all plants was 55 (Table 4).

Table 4

Values of ionic potassium : sodium ratio (K:Na) in plant biomass

| Share of sediment in substratum [%] | Substratum with soil | | | | | Substratum with sand | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | maize | oat | horse bean | lupine | barley | maize | oat | horse bean | lupine | barley |
| | K:Na | | | | | | | | | |
| 0 | 111 | 45 | 88 | 26 | 58 | 130 | 30 | 104 | 33 | 50 |
| 10 | 185 | 25 | 30 | 25 | 61 | 142 | 34 | 39 | 42 | 42 |
| 20 | 141 | 37 | 27 | 34 | 58 | 181 | 35 | 27 | 30 | 43 |
| 30 | 173 | 42 | 17 | 25 | 61 | 152 | 37 | 9 | 25 | 36 |
| 40 | 173 | 31 | 8.7 | 17 | 43 | 191 | 37 | 25 | 26 | 62 |
| 50 | 125 | 37 | 7.5 | 13 | 45 | 143 | 13 | 20 | 17 | 48 |
| 60 | 135 | 35 | 4.0 | 20 | 43 | 177 | 13 | 15 | 17 | 38 |
| 70 | 192 | 32 | 6.2 | 14 | 42 | 129 | 12 | 3.6 | 16 | 26 |
| 80 | 174 | 42 | 5.5 | 33 | 47 | 159 | 24 | 8.3 | 16 | 37 |
| 90 | 154 | 29 | 3.6 | 21 | 41 | 121 | 20 | 5.6 | 19 | 36 |
| 100 | 150 | 23 | 7.6 | 24 | 44 | 150 | 23 | 7.6 | 24 | 44 |
| Mean | 155.7 | 34.4 | 18.7 | 22.9 | 49.4 | 152.3 | 25.3 | 24.0 | 24.1 | 42.0 |
| SD | 25.9 | 7.1 | 24.8 | 6.9 | 8.2 | 22.8 | 9.9 | 28.7 | 8.4 | 9.4 |
| RSD | 16.7 | 20.7 | 132.7 | 29.9 | 16.7 | 15.0 | 39.2 | 119.5 | 34.7 | 22.3 |

Bottom sediment supplement constituting 10 % of the substratum mass caused considerable widening of K:Na ratio in maize biomass but narrowing of its value in horse bean. In biomass of the other plants this ratio value changed only slightly. Further increase in the sediment share in the substrata caused a systematical lowering of K:Na ionic ratio value in oat, horse bean and barley. The share of both elements depended to a greater degree on the amount of added sediment than on the other component of the substratum used in the experiments.

Value of K:Na ionic ratio in plant biomass cultivated in the presented experiments revealed very high changeability depending on the plant species and conditions of the substratum generated by the share of bottom sediment in the substratum. The largest diversification of K:Na ratio (RSD %) in biomass of plant grown on both kinds of substrata was observed for horse bean and the smallest one for maize.

The optimum potassium to sodium ratio amounts to 5–8:1 [9, 16]. The sediment addition to the substrata, based both on soil and sand caused a worsening of interrelations between potassium and sodium only in maize biomass. In the other plants, improved biomass quality was observed assessed on the basis of this parameter [9, 16].

In conditions of variable nitrogen fertilization the values of this parameter in maize ranged from 16 to 24 [17]. These values were almost 10-fold lower than observed in maize biomass in the presented experiment. Wyszkowski [10] found that values of K:Na ionic ratios in spring barley biomass were 108 and in oat 193. These relations between the elements are approximate to registered in lupine, oat and maize biomass in presented Authors' own experiments. Research conducted by Czapla and Nowak [17] shows that value of this ratio in oat biomass at the flowering stage was 5.5 and in barley biomass at the shooting stage reached 6.4 [18]. Shtangeeva and Ayrault [20] report that the values of K:Na ratio in wheat biomass approximated 33.9. As may be seen, the literature data indicate a considerable changeability of potassium and sodium interrelations in plants depending on soil properties and plant species. The value of this ratio in horse bean straw registered in research of Nowak et al [12] was 28. In biomass of lupine, oat and barley obtained in the Author's own research values of this ratio were twice higher than in the experiments of Czapla and Nowak [17]. Value of K:Na ionic ratio in the test plants depended primarily on sodium content changing under the influence of increasing sediment supplements. Changing sodium concentrations in plant biomass caused fluctuations in the value of K:Na ratio, but they were so small that had no greater influence on the plant biomass quality.

The value of K:(Ca+Mg) ionic ratio in plant biomass ranged from 0.24–2.7 (Table 5).

The highest value of K:(Ca+Mg) ratio was assessed in barley and the lowest in horse bean biomass. The largest diversification of this ratio (RSD %) in biomass of plant grown on the substrata with soil was registered for lupine and the smallest one for barley. In biomass of plant grown on the substrata with sand the largest diversification of K:(Ca+Mg) ratio was noted for oat and the smallest one for maize.

A 10 % sediment supplement to the substrata generally led to narrowing of this ratio in plant biomass, except for lupine cultivated on substrata with soil. Bigger admixtures usually did not change its value. The sediment share in the substratum had a greater effect on this parameter value than the kind of the second component. Its changes were the most affected by the changes in calcium and potassium concentrations, whereas magnesium content proved to be less important.

Table 5

Values of ionic potassium : (calcium + magnesium) ratio [K:(Ca+Mg)] in plant biomass

| Share of sediment in substratum [%] | Substratum with soil | | | | | Substratum with sand | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | maize | oat | horse bean | lupine | barley | maize | oat | horse bean | lupine | barley |
| | K:(Ca+Mg) | | | | | | | | | |
| 0 | 1.09 | 0.94 | 0.51 | 0.60 | 2.14 | 1.42 | 2.12 | 0.41 | 1.17 | 2.70 |
| 10 | 1.08 | 0.62 | 0.37 | 1.27 | 1.95 | 0.89 | 0.87 | 0.36 | 0.68 | 1.72 |
| 20 | 0.91 | 0.73 | 0.36 | 0.45 | 1.83 | 0.96 | 0.78 | 0.35 | 0.59 | 1.64 |
| 30 | 0.99 | 1.03 | 0.33 | 0.58 | 1.89 | 0.94 | 0.89 | 0.32 | 0.48 | 1.64 |
| 40 | 0.86 | 0.92 | 0.31 | 0.81 | 1.77 | 0.87 | 0.85 | 0.31 | 0.61 | 1.93 |
| 50 | 0.84 | 0.89 | 0.42 | 0.50 | 2.10 | 0.89 | 0.64 | 0.29 | 0.51 | 2.00 |
| 60 | 0.85 | 1.00 | 0.28 | 0.42 | 1.81 | 1.01 | 0.65 | 0.40 | 0.56 | 1.52 |
| 70 | 0.92 | 0.77 | 0.36 | 0.45 | 2.13 | 0.89 | 0.54 | 0.24 | 0.55 | 1.91 |
| 80 | 0.92 | 1.06 | 0.31 | 0.46 | 2.09 | 1.00 | 0.88 | 0.56 | 0.54 | 2.01 |
| 90 | 0.93 | 1.18 | 0.34 | 0.42 | 1.86 | 0.96 | 0.91 | 0.47 | 0.54 | 1.76 |
| 100 | 0.97 | 0.92 | 0.44 | 0.40 | 1.81 | 0.97 | 0.92 | 0.44 | 0.40 | 1.81 |
| Mean | 0.94 | 0.91 | 0.37 | 0.58 | 1.94 | 0.98 | 0.91 | 0.38 | 0.60 | 1.88 |
| SD | 0.08 | 0.16 | 0.07 | 0.26 | 0.14 | 0.15 | 0.42 | 0.09 | 0.20 | 0.32 |
| RSD | 8.99 | 17.47 | 18.28 | 44.69 | 7.42 | 15.57 | 45.98 | 24.12 | 33.40 | 16.83 |

The optimal K:(Ca+Mg) ratio is 2:1 [16]. In all plants worsening of plant biomass assessed considering this parameter was observed after the bottom sediment application. Value of K:(Ca+Mg) ionic ratio in plants is very important when they are used for feeds because its too high value, which is a consequence of luxury potassium uptake by plants, may lead to hypomagnesemic tetany in cattle. Falkowski et al [9] found that pasture tetanus may occur when this ratio value exceeds 2.5. Ionic ratio between potassium content and the sum of calcium and magnesium in plants in the presented experiments was generally lower than its critical value and in most cases it was below 1. Kaczor [21] observed similar values in orchardgrass on unlimed treatments, whereas liming led to narrowing of this ratio.

In Wyszkowski's research [22], value of this ratio in barley biomass at the flowering stage ranged from 1.95 to 2.35, whereas in oat at the same development stage the ratio assumed values of 2.05–2.35. Generally, these values are several times higher than observed in the Author's own investigations. Wyszkowska [11] found the value of this ratio in horse bean straw slightly over 2.5. Malinska i Pietrasz-Kesik found that K:(Ca+Mg) ratio in maize biomass is 1.25. The main factor modifying this ratio value in plant biomass obtained from the Authors' own experiments was calcium content, the level of which in most cases was increasing after the application of a 10 % bottom sediment admixture to the substratum. Greater changes appeared on the substrata with sand because the plants responded by a higher increase in calcium content in the biomass than the substrata with soil.

Bottom sediment applied as an admixture to soil supplied considerable amounts of calcium which neutralized the substratum. Observed changes of quantity relations between the analyzed elements are similar to assessed after liming [15, 19, 21]. Therefore it may be supposed that agricultural management of dredged bottom sediment as a deacidifying material is possible, however, worsening of some quality indices of the material designed for fodder should be taken into consideration.

## Conclusions

1. Bottom sediment dredged from the Roznow Reservoir added to the substratum caused considerable changes of the value of quantitative relations, particularly Ca:P and K:Na.

2. Bottom sediment supplement to the substratum worsened values of Ca:P and Ca:Mg weight ratios and the value of K:(Ca+Mg) ionic ratio in the first year of the experiment.

3. An improvement of K:(Ca+Mg) ionic ratio was observed as an effect of bottom sediment application in the first year of the experiments.

4. Shaping of weight ratios between the macroelement was affected most by increasing calcium and sodium contents in biomass and considerably reduced phosphorus uptake.

5. An admixture of bottom sediment to the substratum generally worsened quantitative relations between the investigated elements in the first year of the experiment, however it improved the quality of barley biomass cultivated on the same substrata in the second year of the experiments.

6. Dredged bottom sediment affects the quantity relations between the elements in plant biomass in a similar way as liming, therefore the use of this sediment in agriculture is possible as a deacidifying material, however, worsening of some indices of plant fodder quality should be taken into consideration.

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## WPŁYW DODATKU BAGROWANEGO OSADU DENNEGO DO PODŁOŻA NA WARTOŚĆ PASZOWĄ MATERIAŁU ROŚLINNEGO Cz. 2. STOSUNKI ILOŚCIOWE MIĘDZY MAKROELEMENTAMI

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**Abstrakt:** W 2004 i 2005 r. przeprowadzono doświadczenia wazonowe, w których jako podłoża użyto glebę lekką i piasek kwarcowy oraz bagrowany osad denny ze Zbiornika Rożnowskiego. Celem badań była ocena wpływu wzrastających dodatków osadu dennego do podłoża na jakość biomasy uprawianych roślin. Jako kryterium oceny przyjęto wartości stosunków ilościowych między makroelementami w biomasie. Oceniono stosunki masowe Ca:Mg i Ca:P oraz stosunki jonowe K:Na i K:(Ca+Mg).

Wartości stosunku Ca:P w roślinach jednoliściennych z obiektów kontrolnych były zbyt małe, a w roślinach dwuliściennych zbyt duże. Dodatek osadu znacznie rozszerzał ten stosunek, pogarszając na ogół jakość uzyskanej biomasy. W miarę wzrostu udziału osadu w podłożu obserwowano rozszerzenie stosunku masowego Ca:Mg oraz zawężanie stosunku jonowego K:(Ca+Mg), co pogarszało jakość biomasy. Tylko w przypadku jęczmienia uprawianego w drugim roku doświadczeń stwierdzono dodatni wpływ dodatku osadu na kształtowanie się badanych wskaźników jakości paszy. Stosunek K:Na w biomasie wszystkich roślin był zbyt szeroki, a osad dodawany do podłoża poprawiał wartość tego parametru. Pod wpływem dodatku osadu dennego zaobserwowano większe zmiany wartości badanych stosunków w roślinach rosnących na podłożach z piaskiem w porównaniu z podłożami sporządzonymi z gleby lekkiej. Stwierdzono większy wpływ osadu dennego na kształtowanie się wzajemnych stosunków ilościowych pomiędzy badanymi makroelementami w roślinach dwuliściennych niż jednoliściennych.

Osad denny oddziałuje na kształtowanie stosunków ilościowych pomiędzy pierwiastkami w biomasie roślin podobnie jak wapnowania, jest więc możliwe rolnicze wykorzystanie bagrowanego osadu dennego jako materiału odkwaszającego, licząc się z pogorszeniem się niektórych wskaźników wartości paszowej roślin.

**Słowa kluczowe:** osad denny, stosunki między makroelementami, wartość paszowa